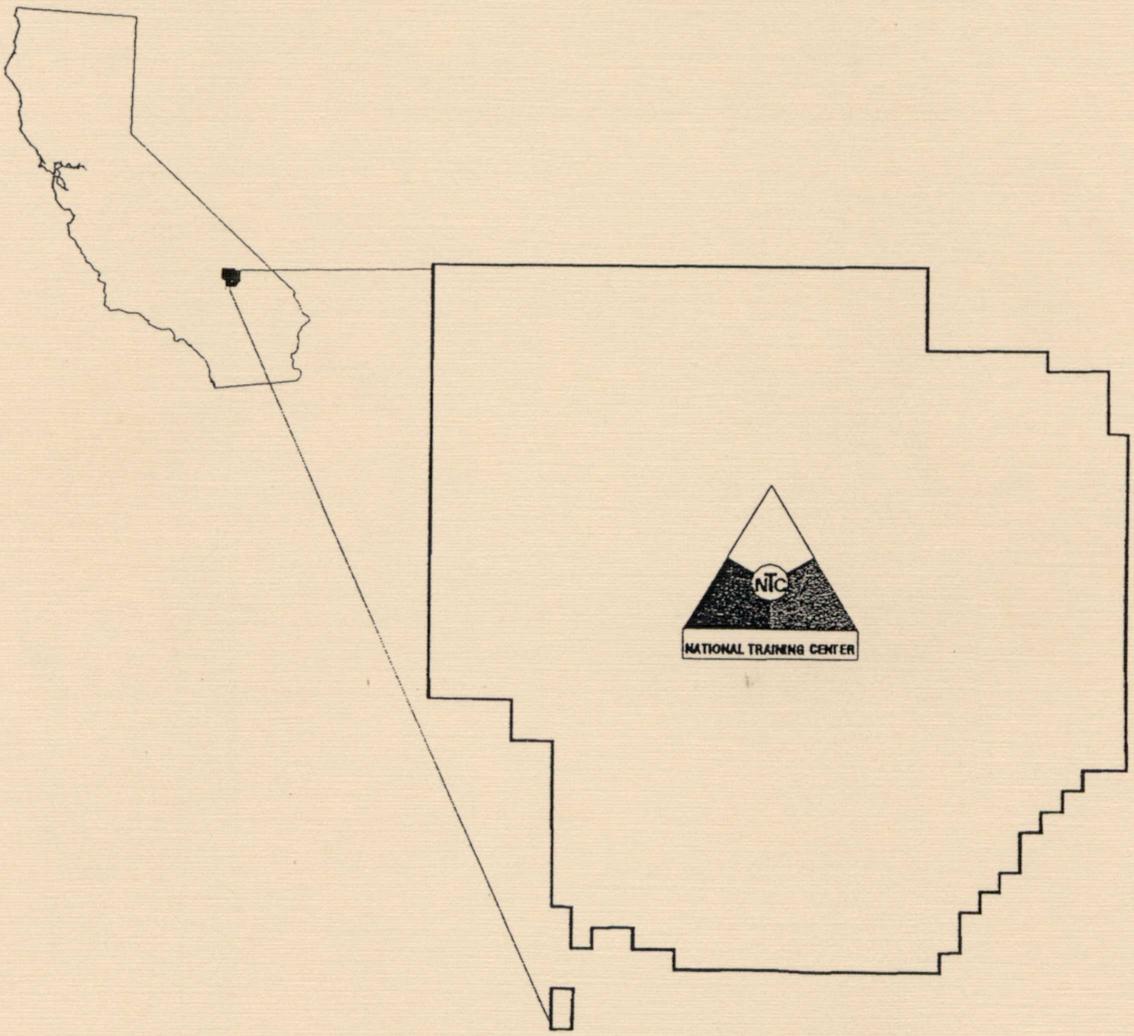
FINAL REPORT

AMPHIBIAN AND REPTILE STUDY ON THE SOUTHERN AND EASTERN PORTIONS OF FORT IRWIN

NATIONAL TRAINING CENTER, FORT IRWIN, CALIFORNIA

December, 1996



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FINAL REPORT

AMPHIBIAN AND REPTILE STUDY OF 20 SITES IN THE SOUTHERN AND EASTERN PORTION OF THE NATIONAL TRAINING CENTER, FORT IRWIN, CALIFORNIA

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ABSTRACT

During the Spring of 1994, a field survey of amphibians and reptiles was conducted across the relatively undisturbed southern aspect of the National Training Center (NTC), Fort Irwin, San Bernardino, California. Fourteen transects associated with four geographically representative hub sites were sampled up to eight times. One creosote transect near Bitter Springs was replicated in both lightly and heavily disturbed portions of same bajada alluvium. A total of fourteen 1000m transects were sampled for diurnal reptiles. Supplemental sampling was conducted in riparian and montane habitats in the more northern Granite and Avawatz mountains. Presence and relative abundance of these taxa were recorded in representative and replicate sites, and organized into major hubs, using a combination of walking plot surveys, pit-fall traps, nocturnal road patrols, and helicopter-facilitated exploration.

Approximately 700 reptiles were recorded, including 11 species of lizards, 3 species of snakes, and one tortoise. This number is only 47 percent of the sample size reported from a similar effort conducted at many of the same (20) sites last year. When proportioned to the increased number of 1994 transects, reported reptiles declined an average of 64 percent per transect sweep from 1993.

Comparisons between the diurnal lizard fauna confirm 1993 studies indicating that discrete saurian assemblages are loosely associated with major habitats discernible by Geographical Information Systems (GIS), especially when both species presence and relative abundance is used in combination. Pilot transects compare lizard assemblages on a less disturbed creosote community with a parallel sample site which was highly impacted by military traffic on the same bajada.

This report describes, evaluates methods and implementation, and presents the results of diurnal transects. Detailed statistical evaluations and integration with the UCLA reptile studies of Goldstone hub suggests that 1994 was an extremely dry year in which populations of the small "annual" side-blotched lizard, *Uta stansburiana*, deteriorated dramatically. Wind velocity may also be inversely correlated with lizard abundance. Disturbance creosote sites appear to favor an increased relative density of the western whiptail, *Cnemidophorus tigris*, which ranked first, above the otherwise most abundant zebra-tailed lizard, *Callisaurus draconoides*.

Recommendations for more effective NTC management of reptile wildlife focus upon:

(1) Improved techniques for sampling.

(2) Framing sampling strategies to include biogeographical faciations as well as ecologically different topographical settings.

(3) The role of lizard samples in ground truthing GIS habitat maps.

(4) The role of herpetofauna in identifying, delimiting, and comparing sites of maximal biodiversity.

(5) Identifying NTC species (herpetofauna) and sites of "special concern," with suggested future monitoring, protection, and management: the lizards *Uma scoparia*, *Sauromalus obesus*, and the snake *Lichanura trivirgata*.

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1.0 INTRODUCTION

In prior Land Condition Trend Analysis of biodiversity at Fort Irwin, reptiles have been reported as incidental components. In contrast, this study, in tandem with a project directed by Dr. Ken Nagy at UCLA, continues the first comprehensive ecological assessment of the base's herpetofauna. This final 1994 report incorporates all requested revisions of the May 1994 preliminary draft.

This augmentation of our 1993 study confirms the primary herpetofaunal associations with major vegetation and substrates in relatively undisturbed settings. Study sites have been spaced at appropriate intervals across the entire base, they sample all three biogeographical subdivisions of the National Training Center (NTC), and they have been balanced in their replicate sampling of all major ecological settings. Lizard surveys are emphasized because these are relatively complete, especially when contrasted to data for more secretive/rare snakes and possible amphibians. Sites have also been selected on the periphery of the base, or they are recessed in montane positions. Both positions are relatively free from the impact of military maneuvers and associated ordnance.

In effect, this study attempted to reconstruct the original herpetofaunal assemblages of the Fort Irwin landscape as it occurred prior to the dedication of this region as a military reservation. These assemblages, when linked to specific vegetation and substrates, will contribute to the generation of thematic maps based upon available the Geographical Information Systems (GIS), which will present hypothetical biotic distributions for the entire base prior to the impact of military operations. By analogy, this study could be described as an analysis of the environmental "block of wood" that constituted Fort Irwin before it was sculptured by human use.

This 1994 study has extended both sites and objectives by establishing new higher elevation study transects in the juniper belt of Avawatz Mountains and by replicating the Bitter Springs Creosote transect in an adjacent setting which is very disturbed by military traffic. Proposed studies for 1995 and subsequent years would expand studies of replicate habitats which differ primarily in degrees of disturbance by military training. Signatures of disturbance as perceived through GIS mapping would guide future studies toward the establishment of trends in ecosystem structure and complexity as they respond to degrees training perturbation. Early empirical findings would generate hypotheses about the quantitative (changes in diversity and relative frequency) ecological consequences correlated to disturbance which would, in turn, be tested by ground truthing the predictions of GIS based estimates of community degradation. In this way, the surveys should not only describe the "block of wood" described in the preceding analogy, but also the depth and scope of the "carving" which subsequent military training has imposed on the original surfaces.

As are most environmental surveys, this study is year and season specific. It basically ranks the relative abundance of the major lizard assemblages occurring in the Spring of 1994, a relatively dry year for this region. A short term pit-fall sample for October is also reported. Subordinate studies of snakes and mesic/montane relict communities involve much smaller samples, and their results are considered problematic.

2.0 METHODS AND IMPLEMENTATION

This section describes the methods used and results produced by their implementation, April through July, 1994. Virtually all assigned field tasks were executed, and most were completed by July 10, 1994.

2.1 SITE SELECTION

Fourteen sites were organized into four major hubs (or units), while the three remaining sites were located in separate upland positions in order to sample remote montane herpetofauna. The four major hubs were selected in order to satisfy the following five criteria:

a. They were the least disturbed examples of major habitat types within or contiguous to Fort Irwin.

b. Each hub included at least four major habitat types recognizable by GIS techniques; each habitat type was contiguous to at least one other habitat which facilitated efficient and localized surveying.

c. Hubs were spaced geographically at least 10 km apart along the east-west axis of the base in order to establish samples which were geographically representative of the entire base landscape.

d. Hubs were chosen which provide replicate sites, not only in soil and vegetation, but also in slope and directional aspect (i.e. north facing slope).

e. Hub locations were also selected for accessibility, both in terms of roads and in terms of avoiding areas frequently closed by rotations of troop training.

f. Sites were selected to complement those hubs operated in the more western Goldstone-Pioneer Deep Space Center by Dr. Nagy's UCLA team, both in geographical setting and habitat types represented.

The four major hubs, from west to east, are:

(1) **Fort Irwin Study Site (FISS)** on the south-eastern corner of the base (35 06'49" N, 116 29' 27" W, 650m elevation); 4 study plots: playa, wash, creosote alluvium, and rock.

(2) **Bitter Springs** eastern border of the base; (35 13' 25" N, 116 25' 42" W, 425m elevation); 6 study plots: playa/alkali, dunes, wash, alluvium, disturbed alluvium (creosote), and rock.

(3) **Red Pass (dry) Lake**-central eastern border of the base (35 15' 45" N, 116 21' 30" W, 582m elevation); 3 study plots: rock, sand dunes, and creosote alluvium.

(4) **Avawatz Mountains** - 2 km south of Cave Springs (35 31' 20" N,116 25' 50" W, 1200m elevation); 2 plots: juniper and creosote on rocky slope.

Each of the preceding geographical sampling localities included at least one of the habitat types listed below. Hubs included either four or five of these categories. At these hub sites, transects were typically arranged into rectangles, or triangles, so that survey teams could continuously sample a different habitat on each side of the quadrilateral without driving to a new locality. Substrate and dominant flora were selected which were generally acknowledged in current literature as good predictors of lizard distributions and which are potentially perceived by remote sensing techniques.

The habitat categories surveyed are arranged in a typically ascending elevational sequence and defined as follows:

a. playa/alkali flat: halomorphic soil on dry lake shores, with or without halophytic vegetation, generally within 25m of shrub vegetation. In 1993, we discovered that local playa/alkali sites are so individually unique, both physically and biologically, that only Bitter Springs alkali study was retained, and only for the purpose of monitoring biodiversity.

b. dune: stabilized and unstable aeolian dunes.

c. wash: fine to coarse sands and gravel, at least 15m across, with or without a bordering riparian vegetation.

d. alluvium: well drained sandy/gravelly fans and bajada dominated by creosote.

e. rocky slopes:

- rocky-creosote, typically below 1100m elevation; in this report granitic substrate (Granites & Avawatz Mts.) has not been separated from basaltic (Red Pass Lake & Bitter Springs). Granitic vs. basaltic outcrops were noted.

- rocky black bush/creosote ecotone, above 1100m.
- rocky juniper/Joshua tree parkland ridge, above 1700 m.

One additional substrate-vegetation type, Joshua Tree-creosote parkland, does occur on the base but only as faciations superimposed on juniper and creosote communities in the Avawatz Mountains. It has been sampled with a creosote undergrowth by the Nagy/UCLA team at the Goldstone Deep Space Center.

2.2 SURVEYS

Staked census transects were sampled a total of eight times. In 1993 generally, sampling was confined to the months of peak diurnal lizard activity. Sampling occurred from June 26 through July 10 at both Bitter Springs and the Avawatz and was limited to peak hours, namely 0700-1430 PST (corrected for daylight savings time). Later hours (past 1300) were reserved for higher elevation juniper sites only. Surveys were generally not run at times when exposed surface ground temperatures were less than 26^0 C or more than 42^0 C (with the exception of a few early July censuses when moderate temperatures were not available). Surveys of a single habitat plot ranged from 20 to 75 minutes, averaging about 45 minutes. Details regarding specific 1994 surveys and their effectiveness are presented in Table 1 (see Appendix D).

The survey teams rotated the timing and sequence in which habitats were sampled at each hub in order to reduce temporal bias. For example, if a rock habitat was sampled first on one morning (when large lizards might not yet be active), it would be sampled progressively one hour later in each of the three remaining days of the survey. Surveyor teams typically consisted of three individuals. They swept a particular transect line with two forward spotters fifteen meters apart, and a recorder walking 10 meters behind the forward pair. Rarely, minimal teams of two were used. Sights were verbally called in to the recorder by species and age-size class (and sex when diagnosed visually). Surveyors also used Pentax 12 X 24 binoculars to enhance their view. The recorder also recorded the number of surveyors, as well as the temperature, wind, and overhead sun exposure at the beginning and end of each habitat survey. Data was recorded in pencil or permanent marker on formal data sheets at the time of observation, photocopied, and then analyzed from Mac Microsoft Excel spreadsheets.

2.3 PIT-FALL TRAPS

Bitter Springs hub was chosen as the focus of our pit trapping efforts. Some of the local area has already been placed off limits. The Springs provides more surface water and desert riparian vegetation than any other site in the eastern half of Fort Irwin. In addition, five habitats, all in good condition ecologically, converge on the Springs periphery to make it the single most valuable environmental monitoring site at the NTC.

Pit traps consisted of 30 cm deep, 15 cm diameter stainless steel canisters with lids. The canisters were covered by 30 cm square dark plastic (Formica type) covers. The covers were braced over the removed canister lids to produce a 2 cm gap, or crawl space, into which reptiles could retreat and subsequently fall into the traps. These containers were placed at 100m intervals, marked by flagged and numbered stakes, in the plot lines of each habitat, eleven per plot. At the zero post of each plot, an additional 20 traps were set in place, five in each cardinal direction, each three meters from the next. The resulting cross pattern was enhanced with 20 cm high allumium drift fencing, held erect by metal posts. These replaced earlier wood posting. The result was 27 traps set per habitat plot, 10 linear and 17 in cross formation. With five habitats sampled at Bitter Springs, this trap system totals 135 operating units. Traps were checked on alternate days during mild spring weather. Because of delays associated with contracting, subsequent troop rotations, and extremely hot weather, the trap lines were run only from June 12-July 1, 1993. A brief follow-up interval of trapping was conducted from October 25-October 29, 1993. In 1994, they were opened from May 1-5 and May 23-29. Encountered squamate reptiles are photographed and released on site, with the exception of a few representative small snakes which are collected for museum documentation. However, even this short interval produced valuable results. All data has been recorded in fashion following that used for the surveys of the same study plots.

2.4 MARK & RECAPTURE (*Phrynosoma platyrhinos*)

While several different methods were contemplated, simple dorsal color pattern/size recognition characters were selected as both adequate and noninvasive. These were recorded by sketch and photo-documentation. Even the use of traditional toe clipping has been implicated in reptile arthritis.

2.5 ROAD PATROLS

Road patrols, just as pitfall trapping, are still in progress. Also, as in trapping, the patrols are confined to a single geographical setting; in this case, the Goldstone Road and its connecting routes (especially Pioneer Road) within the Goldstone Deep Space Center. Nightly logs of mileage are maintained with notes regarding moonlight, temperature, sunset time (PST), and the exact mileage (to 0.1 mi.) for each AOR (alive on road) and DOR (dead on road) reptile encountered. Abundance is estimated against the total number of nocturnal squamate reptiles encountered, and a more absolute density estimation is made for each species relative to the number of miles traveled per night. The latter, coupled with a DOR/AOR ratio, has been incorporated into formulas to estimate annual road losses. Encountered squamate reptiles were photographed and released on site. Data was pooled with Nagy-UCLA results in the final report. It was assigned to specific habitats (playa, creosote alluvium, and basaltic rock-creosote) intersected by defined sections of the sampled roads.

3.0 RESULTS

3.1 SURVEYS

Transect Effectiveness

The survey of fourteen staked plots was completed by July 1, 1994. The sites and habitats represented by these plots were selected according to the criteria already described in Methods. A total of 707 reptiles were recorded. This constitutes 49 percent below the total number recorded in 1993. When the differences in transect numbers (twenty in 1993 versus fifteen in 1994) and frequency of samples (four versus eight) are considered in proportion to the average number of reptiles per transect, the decline in encounters is even more apparent. The average number of reptiles reported per transect walk was 8, while the average for the previous year was 22. Measured by this more proportional index, reptile abundance had declined by 64 percent since 1993.

Table 1 summarizes the conditions and performance of site specific sampling in 1994. The appendix includes a more rigorous graphical and statistical analysis correlating times, temperatures, and ambient conditions with both individual and species abundance.

Transect Census Counts

Ninety nine percent of these individuals belong to twelve species of diurnal lizards. The explicit findings by habitat and geographical hub sites are presented in Table 2 (Appendix D).

Appendix B provides bar graph and tabular summaries of relative abundance (as percentages of each total sample) of diurnal lizards as recorded in Table 2. This information is organized primarily by habitat and secondarily by geographical hub site. In Table 2 Relative Abundance of Diurnal Lizards within Major Habitats of the National Training Center, Fort Irwin, the raw numbers for the same samples are displayed, but with organizational emphasis reversed with hub affiliations being primary. Table 2 also reveals herpetofaunal characteristics which discriminate between habitats.

Even among the six diurnal lizard species which were widespread among habitats, differences in relative abundance effectively separated one habitat assemblage from another. These six widespread species are: *Callisaurus draconoides, Cnemidophorus tigris, Dipsosaurus dorsalis, Gambelia wislizenii, Phrynosoma platyrhinos*, and *Uta stansburiana*. The latter species illustrate this point most vividly: *U. stansburiana* occurs at virtually all localities, yet it varied from a high of 82.4 percent in Juniper scrub parkland in contrast to 3.1 percent in creosote alluvium. Similarly, the widespread C. draconoides is 65 percent (as high as 94 percent at FISS) of the total saurian fauna of washes, but only 0.3 percent of that fauna in creosote rock slopes. These contrasting figures are drawn from the combined extreme values reported in 1993 and 1994.

Another set of lizard taxa characterizes habitats qualitatively by presence or absence, rather than quantitatively. These six habitat specialists are: *Crotaphytus bicintores, Sauromalus obesus, Sceloporus magister* and *S. occidentalis* (both usually habitat generalists, but apparently more restricted at the NTC), *Uma scoparia*, *Urosaurus graciosus*, and *Xantusia vigilis*. The first two species were confined entirely to creosote rock slopes, the third to creosote-blackbush supporting some Joshua trees or Mojave Yucca (*Yucca brevifolia* and *Y. schidigera*, respectively). *Sceloporus occidentalis*, very widespread across northern California and Nevada, was entirely confined to relict Juniper parkland above 1700m elevation (on the north slope) at the NTC. This 1993 record was the first for that species from the base. The desert night lizard, *Xantusia vigilis*, was recorded in this relict woodland. However, subsequent and combined studies demonstrated that its presence is generally predicted not only by the presence of Joshua trees and by other microhabitats in alluvial creosote habitat and microhabitats, including *Neotoma* midddens (Morafka and Banta, 1972).

The arenicolous *Uma scoparia* was entirely confined to dunes and dune-wash interfaces, while the arboreal *Urosaurus graciosus* exceeded 3 percent of the lizard fauna only in dune, one wash, and alkali-playa habitats. These last two species constitute new records for NTC, Fort Irwin (Joyner-Griffith, 1991). *Urosaurus* was present in exceptionally high densities in Bitter Springs alkaline/playa edge/wash and dune vegetation (*Atriplex*). The two new *Uma* populations, again discovered in 1993 at Bitter Springs and the hillside sand sheet on the east face of Red Pass, and on dunes along the northwest shore of Coyote Lake (Kaufman, personal communication) represent considerable gap fills for the region intervening between Pisgah Crater on the south and the Little Dumont Dunes to the east in the Silurian Valley and the northernmost population at Saratoga Springs (Death Valley National Park).

Undisturbed Versus Disturbed Creosote Bajada Transect Comparison

The following summary data compares undisturbed versus disturbed transect results for a creosote dominated bajada just east of Bitter Springs:

Critical evaluations of the results of Table 3 (Appendix D) will await multiyear analyses which identify repetitive weather based correlations. However, the patterns described here will become critical in expanded future studies of trends in land use for two reasons. First, creosote alluvium is, broadly speaking, the dominant land form most frequently transversed by military maneuvers, and second, this is our first pilot study attempting to correlate degrees of land surface disturbance with changes in lizard assemblage density and/or relative frequency. This preliminary survey of results offers only the following observations:

- The most profound consequence of disturbance appears to be the depression in total numbers of individuals. The frequency with which lizards were encountered on an averaged transect dropped by 70 percent.

- In contrast, declines in lizard frequency between a wet 1993 and a drier 1994 in undisturbed Bitter Springs creosote was only 32 percent.

- In all these samples the dominant species are the zebra-tailed lizard, *Callisaurus draconoides*, followed by the western whiptail, *Cnemidophorus tigris*. However, in the disturbed habitat, the whiptail was relatively more abundant. Figure 1 (Appendix B) displays a Callisaurus: Cnemidophorus ratio of 7.56:1 in undisturbed habitat, but this declines to 1:075 in the transects set in disturbed creosote. In contrast to the combined 1993 percentages, the 1994 undisturbed creosote sample ranked the whiptail and the desert iguana, *Dipsosaurus dorsalis*, in a tie for second place for relative abundance. The desert horned lizard, *Phrynosoma platyrhinos*, was actually more abundant at the disturbed transects in the 1994 comparison with controls.

- When less abundant species are included in the totals for species density, the outcome is counter intuitive. Specifically, the disturbed transect with smallest sample size in terms of individuals actually has five species to the undisturbed 1994 value of three species. However, the 1993 tally for the undisturbed Bitter Springs transect was six species. Wet year versus dry year differences might explain the latter discrepancy, but the larger 1994 sample size in terms of individuals make this hypothesis questionable. The greater taxonomy density on disturbed sites might be simply an anomaly, produced by small sample size in a single season study. However, sustained and expanded results supporting this pattern might indicate more thermal and substrate heterogeneity in a disturbed setting, possibly inducing the kind of species packing associated with ecotonal or mild disclimax conditions in secondary succession. Alternatively, the disturbed transect may intercept complex terrain and/or vegetation which does not entirely parallel its "undisturbed" counterpart.

- All creosote-alluvium transects rank the relative frequency of the ubiquitous side-blotched lizard, *Uta stansburiana*, at less than 10 percent of the total with exception of that sampled at the Avawatz hub. Here, side-blotched lizards constitute 64.7 percent of the total, suggesting a habitat and/or temporal weather pattern which distinguishes this sample from the rest. In almost any habitat, cool weather or very early morning sampling will favor increased relative abundance of this small heliotherm over other species, and some transect data sheet weather/time reports favor this hypothesis as a partial explanation. However, statistical correlations indicate the 1994 decline in juvenile side-blotched lizards, especially at the Goldstone control sites, determined the overall reduction in the species (Brown and Nagy, 1995). In addition higher wind velocities were better predictors of lower lizard densities than were extreme temperatures.

3.2 PIT-FALL TRAPS

In 1993 the combined results for all plots reveal the presence of new taxa not previously recorded, and unusually high percentages for some species. The 1993-1994 results are summarized in Table 4 (Appendix D).

These results include three species, all typically nocturnal, which were not revealed by daytime walking surveys of adjacent plots. The three species were the two small insectivorous snake species, *Chionactis occipitalis* and the ant colony "parasite" *Leptotyphlops humilis*, and the gecko, *Coleonyx.* Four of the five *Chionactis* were recovered from pit-falls in the creosote alluvium plot. The recovery of so many individuals in such a small, 500m X 100m, area in so short a period indicates very high densities for this species compared to other snakes. These results are consistent with the Banta (1963) pit-fall trap results for Saline Valley, and with the low trophic position of this insect and scorpion predator. The nocturnal ground gecko, *Coleonyx variegatus,* was also recorded. In 1993 only 10 nocturnal rodents were recovered from the traps, typically *Peromyscus*, but occasionally young *Dipodomys*, *Perognathus*, and *Onychomys* were also recorded. Tenebrionid beetles and scorpions were also frequent in the traps.

While the pit-fall results generally parallel those walking surveys of the same plot, several conspicuous differences are also apparent. As an illustrative example, in 1993 *Callisaurus* constituted 37.9 percent of the Bitter Springs wash plot survey, in contrast to 13.5 percent of the pit-fall captures for the same wash plot. For this plot, *Cnemidophorus* comprised 6.8 percent of the lizards observed in walking surveys, but 27 percent of the reptiles recovered by pit-falls. The 1994 samples are too small to legitimize such comparisons, but higher frequencies of snakes and geckos, collectively 46 percent of this year's total, indicates that the traps sampled a very different subset of the herpetofaunal assemblage than that encountered in walking transects, and much of it nocturnal. Interestingly, this 46 percent nocturnal herpetofauna is an order of magnitude greater than was recorded last year (4.3 percent). Perhaps the early 1994 trapping, May, rather than June and July, contributed to this outcome. Independent of the calendar differences, slightly cooler and possibly moister substrate conditions might also have facilitated nocturnal activity.

3.3 MARK & RECAPTURE (*Phrynosoma*)

The yield of horned lizards, *Phrynosoma platyrhinos*, was inadequate, even in the best of plots, to sustain an effective mark and recapture program. No more than three animals were sighted per transect and none of these represented recaptures either from this year or last.

3.4 ROAD PATROLS

Preliminary road patrols at the Goldstone Deep Space Center yielded fifteen reptiles over a three day period. A total of 120 km was patrolled over the three nights of June and August, 1994. Patrols were conducted by a single vehicle with two observers from 1930 hrs to 2130 hrs PST. In 1993, rates of encountering reptiles averaged 1.25 reptiles/10 km and 2.5 reptiles per hour. In fact, most individuals were discovered AOR (alive on road) on paved roads in playa or creosote alluvium between 1930 hrs and 2015 hrs. Appendix D lists the seven species of snake and one species of lizard reported from the road patrols. One third of all specimens were small adult sidewinders, *Crotalus cerastes*. All specimens were released, most after photo documentation. Ms. T. Brown (of our counterpart team from UCLA) has recorded at least four additional snake species from this immediate area, as presented in our combined 1993 final report.

During 1994 runs, reptile encounter rates at Goldstone were an order of magnitude lower than those reported in 1993. Based upon the few June, August, and September sample nights, one individual was encountered approximately an average of 50 km travel after three hours of effort. Of five reptiles recorded, again, the sidewinder, *Crotalus cerastes*, was the conspicuous dominant, accounting for 40 percent. On September 29, 1994 the first appearance of a neonate sidewinder was recorded. Extending patrols in Spring, 1995 should considerably expand our database.

One major achievement of the 1994 summer survey was the mapping of the Goldstone Road segments against adjacent plant communities. While the Goldstone Road proper traverses primarily alluvial creosote habitats pocketed with outcrops, the paved service road to Pioneer Station, which branches from it, passes through a considerable basaltic hillside. Below is presented a mileage log of vegetation - substrate changes along Goldstone Road and the paved spur to Pioneer Station.

4.0 DISCUSSION

4.1 EFFECTIVENESS OF TECHNIQUES

Considering the short time in which this project has been in operation, techniques have generally proven very effective. Walking plot surveys of the four hub sites, establishing diurnal lizard faunas, appear to be the most reliable. Even the relative abundance values presented in the report should be adequate for thematic mapping. However, delayed implementation of the 1994 study did take its toll on sampling effectiveness. From October 1993 through November 1994, the total precipitation for these 14 months at the Bicycle Lake weather station was only 25 mm, or about 25 percent of normal. NOAA 1992-94 weather data for Goldstone has already been cited by Brown and Nagy (1995). They indicated that precipitation dropped 80 percent (55mm) for the year beginning May 1993, relative to the previous year (273mm). Poor yields in lizard transects were more often reflected in smaller sample sizes than in species absence. The 64 percent reduction in average transect counts was due, in part, to sampling which fell outside of our 0700-1300 hrs PST and 28-46^{0}C air temperature ranges and our July sampling. We now recommend that all samples be confined to days 140-180 Julian calendar, to 0700-1200 hrs PST, to air temperatures 26-46^{0}C, and ground surface temperatures 28-52^{0}C (see Appendix C: Statistical Summary).

The remaining montane sites are considered as tentative and should be supplemented with additional survey runs. Likewise, pit-fall and Goldstone Road patrol results clearly have not reached the asymptotes of their respective species/area or species/time curves. The previous section on results reveals how effective all of these approaches have been. Less apparent are the limits/biases inherent in each of the approaches. The overall effectiveness of the techniques employed are summarized below:

(1) Diurnal lizard habitat plots did not alter species or relative abundance dramatically in up to eight surveys, indicating the stability of results. However, in no case should these values be considered true measures of absolute density for any species.

(2) As noted in the results, plot survey and pit-fall results revealed reciprocal biases. Plot surveys generally failed to reveal nocturnal species, especially the gecko *(Coleonyx variegatus)* and the western shovel nosed snake (*Chionactis occipitalis*), both of which were repeatedly found in traps. The traps were also successful in capturing large lizards, such as *Dipsosaurus dorsalis* and *Gambelia wislizenii*, though they would most certainly fail to confine an adult chuckwalla (*Sauromalus obesus*) or a snake over 50 cm in total length. The trap appeared to be differentially attractive to the active foraging lizard *(Cnemidophorus tigris)* as noted

previously in results. As in the case of plot surveys, seasonal biases remain unresolved. Not only is hatchling emergence an issue, but fall, winter, and early spring activity by secretive mesic taxa might augment or alter results considerably. Small snakes such as *Tantilla hobartsmithi* or *Diadophis punctatus* could be collected during cool winter periods, as could amphibians like the red spotted toad (*Bufo punctatus*). Joyner-Griffith (1991) discovered the desert night lizard (*Xantusia vigilis*) in pit-falls in Fort Irwin habitats devoid of the Joshua tree litter with which this species is often associated. This taxon is also well documented as winter active (Morafka and Banta, 1972).

(3) As noted previously, road patrols, as well as mesic and montane sampling, operated on too small a scale for complete evaluation, although all three approaches appear to be highly effective.

4.2 ECOLOGICAL PATTERNS FOR GIS APPLICATIONS

This discussion will be confined to the use of diurnal lizard surveys of the six best sampled habitat types: playa, dune, wash, alluvium-creosote, rocky slope-creosote, and yucca-creosote-alluvium. All of these land forms are sufficiently developed topographically at Fort Irwin to be discerned, at least potentially, by remote sensing GIS (Lee, 1995). As observed in the results, especially Table 2 and in the Appendix, each of the habitat types has lizard assemblages which may be distinguished by combinations of presence/absence data and relative abundance. However, this claim requires three qualifications:

First, statistical assessment of differences within the same creosote habitats at different sites under different training conditions indicate that the following pairwise comparisons are significant at $P < 0.05$: Bitter Springs disturbance vs. control sites (Fisher PLSD, Schheffe F-test) and Avawatz control site vs. Bitter Springs control site (Fisher PLSD only). Second, washes vary tremendously in size, connectivity, and associated vegetation. They vary individually in a fashion similar to playa (although over a more narrow range). Both categories have been omitted from Table 5 (Appendix D).

Finally, the data presented in this report does not evaluate possible distinctive assemblages embedded within the current divisions. For example, in 1993 the arboreal specialist, *Urosaurus graciosus,* constituted 8 percent (and a remarkably consistent 7.3 percent in 1994) of the lizard fauna in the playa/alkaline vegetation of Bitter Springs, but it was not recorded at all from the same habitats at the Red Pass Lake, Mannix, or FISS hubs. This and other differences in presence and abundance make suspect the merging of all "playa" data. It may prove to be more accurate to subdivide this category into: Atriplex-alkaline flat (Bitter Springs), Atriplex playa shore (Mannix), creosote-playa shore (Red Pass Lake), and crucifixion thorn/creosote small playa shore (FISS). Similarly, the rocky slope-creosote habitat includes both granitic (Mannix and FISS) and basaltic (Bitter Springs and Red Pass Lake) substrates. These might also be productively subdivided, though the preliminary data indicates the presence of the same characteristic lizards (*Crotaphytus* and *Sauromalus*) in both.

4.3 ECOLOGICAL AND HISTORICAL BIOGEOGRAPHICAL SUBDIVISIONS OF FORT IRWIN

Two historical aspects pertain to the ecology of Fort Irwin herpetofauna. First there is the apparent lack of desert riparian amphibians and mesic reptiles in Fort Irwin wetlands. These assemblages are well developed just south of Fort Irwin in Paradise Springs (Pacific tree frog, *Pseudacris (Hyla) regilla*, and the western and red spotted toads, *Bufo boreas* and *B. punctatus* respectively), in Furnace Creek to the north (*B. punctatus*, Death Valley National Park), and in Afton Canyon to the southeast of the base (the pacific pond turtle, *Clemmys marmorata*, the toad, *B. boreas*, and the introduced bullfrog, *Rana catesbiana*). The absence of these taxa from the very small and isolated wetlands of the base may be the result of extirpations brought about by drought in the Early Holocene Xerothermic period or subsequent altithermals. Mesic relicts may be attributed geographically to three major mesic physiographical and ecological wetlands of pluvial and early Holocene antiquity: Lake Manley to the northeast (now Death Valley), Lake Mannix to the south (now Coyote Lake and associated surface water, such as Paradise Springs), and the Pleistocene Mojave River.

However a second set of findings so indicates the presence of two relict members of the Fort Irwin herpetofauna, *S. occidentalis* and *Sonora semiannulata*, now more typical of cooler or more mesic deserts to the north and east. These may be relicts of more continuous populations which existed during the cooler climatic fluctuations in end Pleistocene Epoch (12,000 years ago), early Neoglacial (3,600 yrs BP), and even the historic "little ice age" of several hundred years past. Enzel et al (Enzel, Cayan, Anderson, and Wells, 1989) made a paleoclimatic reconstruction of the nearby Silver Lake Playa. Van Devender (1987) described a Pleistocene Mojave desert herpetofauna superimposed with pinyon-juniper biota reconstructed from fossil wood rat middens. Certainly, the *S. occidentalis* and *Sonora* would be more typical of the Great Basin Desert to the north and east. Thus, despite our poor preliminary results from Fort Irwin wetlands of Cave Spring, Arrastre Spring, Bitter Spring, and Jack Spring, additional efforts should be made to seek mesic/cooler climate relict herpetofauna. Candidate species for continued searches include the snakes *Coluber constrictor, Masticophis taeniatus, Tantilla hobartsmithi,* and *Diadophis punctatus;* the lizards *Eumeces gilberti* and *Elgaria panamintineus*; and anurans such as *Bufo boreas*, *B. punctatus*, and *Hyla regilla*. Some of these mesic northern and eastern taxa may still occur on the base, even as rare or restricted relicts.

Based on the foregoing ecological and paleontological information, the extant biota of Fort Irwin may be divided into three biogeographical subdivisions, even though all remain within the geographical boundaries of the Mojave Desert. These subdivisions or faciations might be characterized as follows:

1. **Great Basin Desert**: a relict biota adapted to cool semi-arid climates of higher elevation (above 4000 ft) is present in the Granite and Avawatz mountains. These ranges may be more influenced by Great Basin taxa because of their northern and eastern geographical position proximate to the Garlock Fault which forms the southwestern border of the physiographical Great Basin. The relictual biota resident in these montane refugia is sustained in local climatic regimes which were more typical of the aforementioned glaciopluvial Mojave Desert region lowlands. Given the widespread distribution of these taxa during the Pleistocene, elevation may play a more important role than geography in sustaining these cooler climate species. Taxa include not only the aforementioned reptiles, but juniper woodlands and black bush scrub as well. Possible indicator reptiles include the Western Fence Lizard (*Sceloporus occidentalis*) and the Ground Snake (*Sonora episcopa*), although the distribution of the latter remains problematic. The presence of the Panamint rattlesnake, *Crotalus mitchellii stephensi*, north of the cantonment, further supports recognition of this faciation/ecotone. Typically Great Basin sage sparrows and heteromyid rodents are also present at the NTC, although not always confined to its upland north.

2. **Western Mojave Desert**: This complex of creosote covered bajada, Joshua tree parkland, and *Atriplex* dominated playa edge characterizes most of western and south central portions of the NTC. That portion of Fort Irwin south of the Granite and Avawatz mountains, largely west of the Mannix Trail, and which lies between 2500-3800 ft elevation is within this subdivision. Characteristic herpetofauna of these upland, but still warm desert, habitats include both the desert night lizard (*Xantusia vigilis*), the rosy boa (*Licanura roseofusca*), and the Mojave rattlesnake (*Crotalus scutulatus*). Desert tortoises (*Gopherus agassizii*) would be also typical, but they are not entirely confined to this subdivision.

3. **Colorado Desert Ecotone - Baker Sink**: This smallest subdivision is confined to the Southeastern corner of the base, namely the lowlands (below 2500 ft elevation) and playas east of Mannix Trail. The low sandy valleys and slopes associated with Bitter Springs and Red Pass Lake are adjacent to BLM lands to the south and east along the Mojave River drainage (Cronese lakes, Afton Canyon, Soda Dry Lake, and Kelso dunes). While creosote still dominates the landscape, Joshua trees are largely absent. Immediately south of FISS occurs crucification thorn, otherwise characteristic of the Colorado Desert. A characteristic reptile of this area is the Mojave fringe-toed lizard (*Uma scoparia*). While not entirely endemic, the western blind

snake (*Leptotyphlops humilis*) and the longtailed brush lizard (*Urosaurus graciosus*) are found much more consistently on this portion of the NTC. In contrast to the northern NTC, the local subspecies of the saxicolous speckled rattlesnake occurring here is *Crotalus mitchelli pyrrhus*, typically of the lower Mojave and Colorado Deserts.

4.4 RECOMMENDATIONS FOR NTC MANAGEMENT

Recommendations for more effective NTC management of reptile wildlife focus upon five suggested actions:

(1) **Improve techniques for sampling**. Diurnal lizard surveys should be supported by on-site rain gauges as well as current temperature monitoring. Sampling must be standardized and optimized by confining sample periods to Julian days 140-180, PST 0700-1300 hrs, soil surface temperatures of 26-48^{0}C, and low wind velocity (< 25 kph). This latter factor, a statistically significant predictor of epigean lizard activity, had not been fully considered in the past (see Brown and Nagy, 1995 and this report, Appendix C: Statistical Summary).

(2) **Frame sampling strategies to include biogeographical faciations as well as ecologically different topographical settings.** This strategy also requires that NTC biota be considered in context with natural biogeographical regions, not military reservation boundaries. Therefore, delimiting the borders/ interfaces between Mojave, Great Basin, and Colorado Deserts is a critical prerequisite to evaluating regional differences within the NTC itself.

(3) **Expand the role of diurnal lizard samples in ground truthing GIS habitat maps.** During spring and early summer, diurnal lizard census transects provide a low cost, rapid mechanism for ground truthing major habitats perceived/predicted from GIS remote sensing. Four virtually ubiquitous species *Callisaurus draconoides, Cnemidophorus tigris, Phrynosoma platyrhinos,* and *Uta stansburiana* may be used to test new creosote scrub, wash, and rocky outcrop sites simply by establishing their ranked relative frequencies. Four other species indicate specific habitats/substrates by their simple presence or absence: *Sauromalus obesus* and *Crotaphytus bicinctores* indicate rocky substrates; *Uma scoparia* is an indicator of aeolian sandy dunes; and *Urosaurus graciosus* indicates significant vertical structuring of vegetation, particularly as manifest by desertoriparian plants. Several other species may be indicators of geographical and physiographical features: *Sceloporus occidentalis* is confined to elevations above 1500m; *Sceloporus magister* is absent from the treeless lowlands south and east of Langford Lake; and *Dipsosaurus dorsalis* is absent from the upland west and north of the NTC, above 1100m. Along with plants and insects, diurnal lizards are particularly accessible indicator species for ground truthing habitats originally perceived by their GIS signatures.

(4) **Identify NTC species (herpetofauna) and sites of "special concern", with suggestions for future monitoring, protection, and management.** Currently the desert tortoise is the only state and federally recognized threatened reptile species on the NTC. However, the California Department of Fish & Game (Jennings and Hayes, 1994) lists the following amphibians and reptiles which occur on the NTC, or within 50 km in habitats replicated on the base, of "special concern" (a possible prelisting designation):

Salamanders: none, however the Inyo Mts. Salamander (*Batrachoseps campi*) should be searched for at Hell Wind Canyon and in the Springs of the Avawatz Mts.

Anurans: none discovered, but the red spotted toad (*Bufo punctatus*), the western toad (Bufo boreas), and its unnamed Afton canyon derivative, the Pacific tree frog (*Pseudacris regilla*) should all be expected in NTC wetlands.

Lizards: The Mojave fringe-toed lizard (*Uma scoparia*) is well represented in the Bitter Springs dunes, currently NOT off-limits to training. The Panamint alligator lizard (*Elgaria* *panamintina*) occurs peripheral to the northern NTC in the Argus Mountains and at elevations down to 760m in riparian canyon habitats (Jennings and Hayes, 1994). Granites, Hell Wind Canyon, and Avawatz should be investigated for its occurrence, especially where thickets of *Baccharis, Clemantis*, or *Vitis* occur. While not listed by the California Department of Fish and Game, the distribution and demographics of the chuckwalla (*Sauromalus obesus*) should also be carefully monitored at Fort Irwin since it is a particularly large, long-lived, and herbivorous lizard and potentially a sensitive indicator species. The venomous Gila Monster (*Heloderma suspectum*) is another large lizard and a species of "special concern" which does occur east of the NTC in the Providence Mountains, but is not expected to occur west of the Baker Sink or in the NTC.

Localities sustaining rich assemblages of herpetofauna or rare individual species will generally be associated with wetlands, montane woodlands, dunes, and other specialized substrates which are themselves both rare and isolated. Provisionally, it is recommended that all sites be placed off-limits, at least to terrestrial vehicles and maneuvers, until a preliminary survey of sites might be completed in 1995-96. Then such habitats might be evaluated for their biotic value, and the more substantial units organized into buffered and interconnected reserve systems, following designs and procedures outlined by Shafer (1990). For herpetofauna with very limited agility and dispersal properties, Shafer's (drawing on Preston's 1960 Ecology 41: 611) distinction between isolates (islands) and samples (derivative subsets) is particularly useful in modeling assemblages of mesic relict herpetofauna. These are better characterized Holocene "samples" of more complete Pleistocene communities than as "islands" approaching equilibrium. Item #5 below will explain further how such biodiversity sites are better defined, compared, and ultimately, managed.

(5) **Expand the role of herpetofauna in identifying, delimiting, and comparing sites of maximal biodiversity.** The distribution of indicator reptile species may assist the Department of Public Works with a systematic inventory of NTC mesic habitats (here defined as springs, riparian vegetation supported by subsurface water, and juniper woodlands), their coordinates, surface area, geology and hydrology, and representative vegetation, insects, and other vertebrates. Statistical/quantitative comparisons of sites should be made in both biogeographical and ecological contexts. Future studies could provide preliminary data for the formulation of a coordinated interdisciplinary five year plan for the further investigation, management, and when necessary, mitigation for training impacts on mesic habitats. Tasks in support of this effort would include:

a. establish a checklist, with Global Positioning Systems (GPS) coordinates, of all mesic NTC sites;

b. schedule a series of sites visits by the team, each session extending 5-10 days;

c. photograph all sites from air (we will need helicopter time) and ground;

d. take soil and water samples, as available, from all sites, and pilot pit-fall trap samples (insects, herpetofauna) from selected sites;

e. calculate surface area of all sites;

f. construct species density-to-surface area correlations, geographical cluster analyses, and test island equilibrium and sample-subsample predictions in future studies of representative sites and taxa in a comprehensive five year plan.

Products generated by the program of study just suggested include:

- A gazetteer and illustrated atlas of NTC mesic habitat sites including detailed profiles for most sites (profiles will provide GPS, surface area, water and soil characterizations, checklists of vascular plants, insects, herpetofauna, and birds).
- Quantitative comparison of sites correlating surface areas, elevation, and physical habitat characteristics with species diversity for major taxa.

- Biogeographical comparison of sites, examining historical refugia, island equilibrium, and sample-subsample models to explain differences in biodiversity; gap analyses should also compare the percentage of each major ecotype which is impacted versus protected, either passively by lack of training or actively by "off limit" set asides.

- A master five year plan for the investigation of and management of NTC mesic habitats.

The final result of such an effort would be an empirically based and systematically developed master plan for biodiversity management at the NTC, rather than a reactive and piecemeal "discovery" of vulnerable and valuable sites and ecosystems, one at a time. This same systematic approach could be applied to other landforms (i.e., dunes and limestone outcrops) putatively harboring high biodiversity, or to rare relict or substrate specific taxa.

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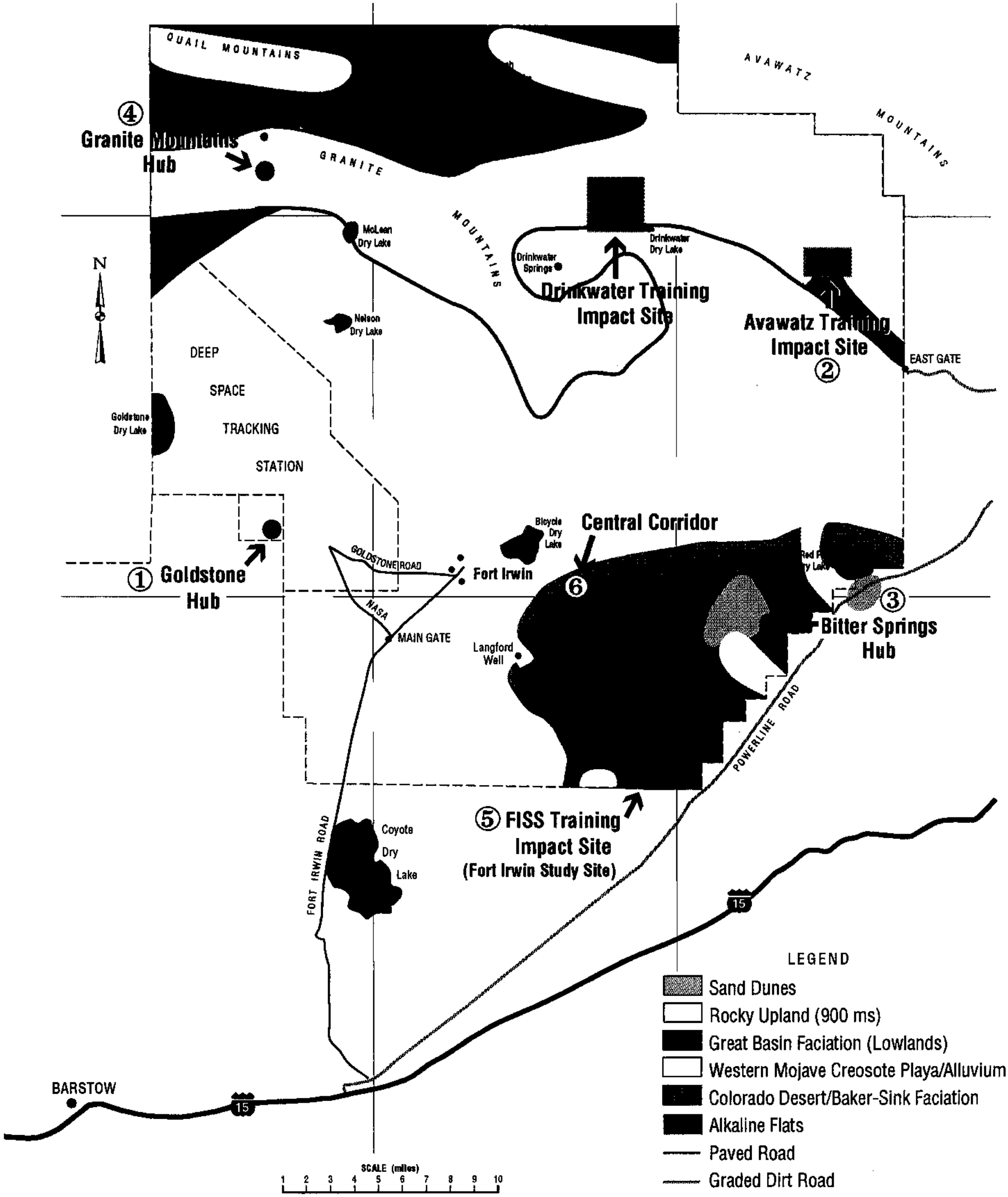
APPENDICES

APPENDIX A

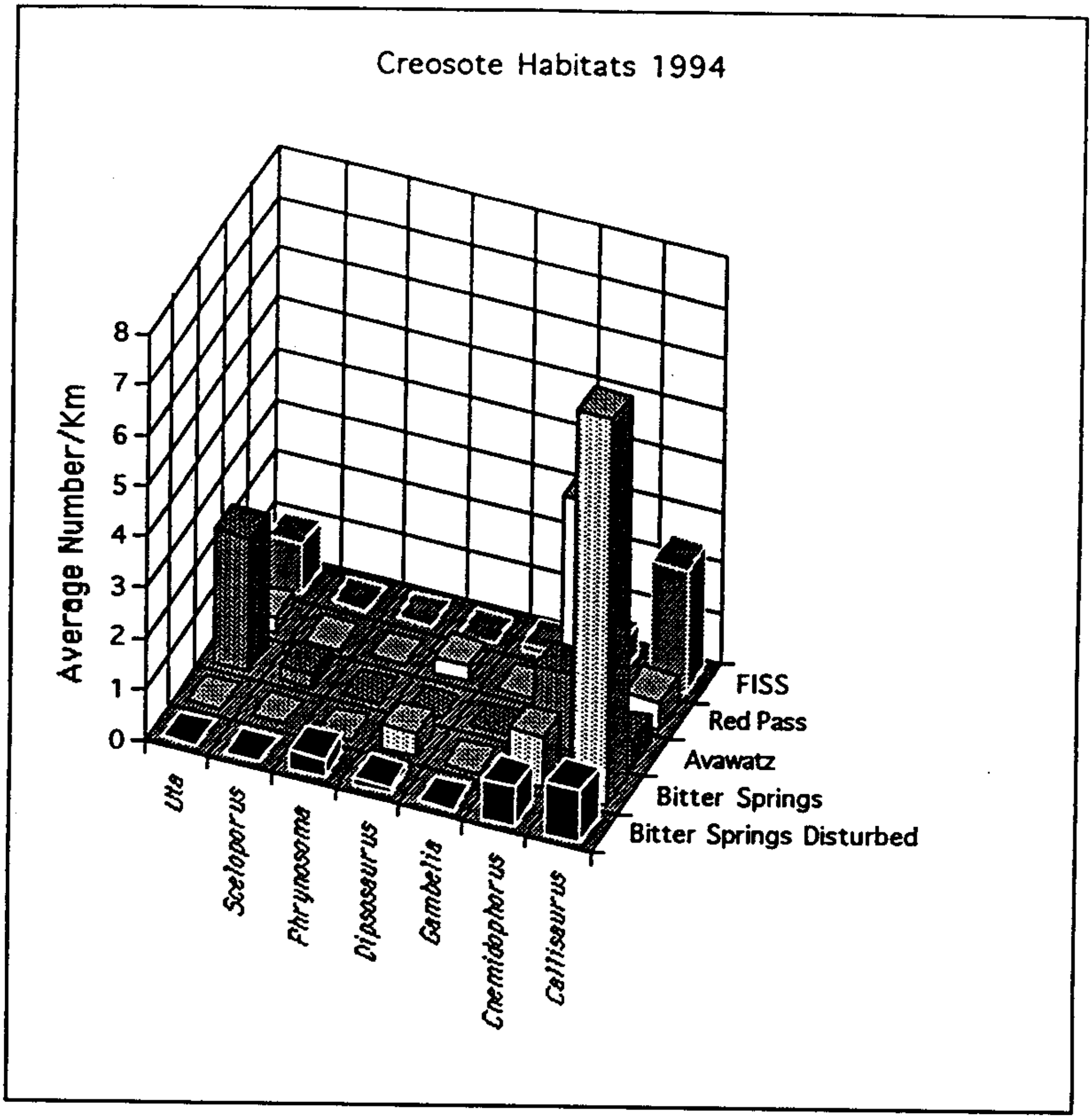
Map of Hub Sites on the NTC

Habitat Distribution and Training Impact Study Sites at Fort Irwin National Training Center



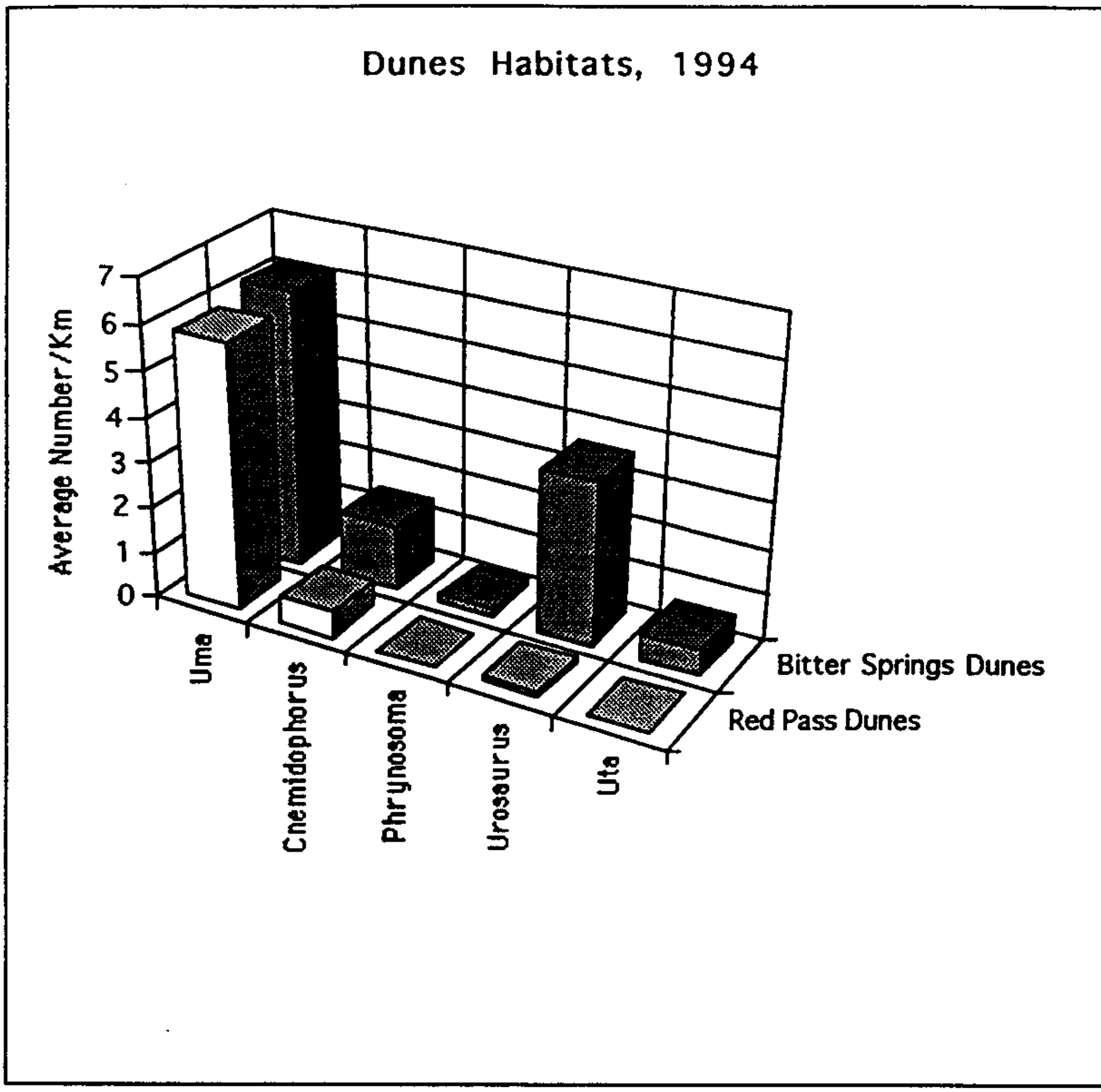
APPENDIX B

Relative Frequency for Each Lizard Species Recorded for Each Transect, 1994 Data Combined by Habitat Type



	FISS	Red Pass	Avawatz	Bitter Springs	Bitter Springs Disturbed
Callisaurus	2.400	0.570	0.500	7.560	1.000
Cnemidophorus	0.570	4.100	1.500	1.000	0.750
Gambelia	0.140	0.000	0.000	0.000	0.000
Dipsosaurus	0.000	0.290	0.000	0.440	0.125
Phrynosoma	0.000	0.000	0.000	0.000	0.375
Sceloporus	0.000	0.000	0.250	0.000	0.000
Uta	1.000	0.290	2.600	0.000	0.000

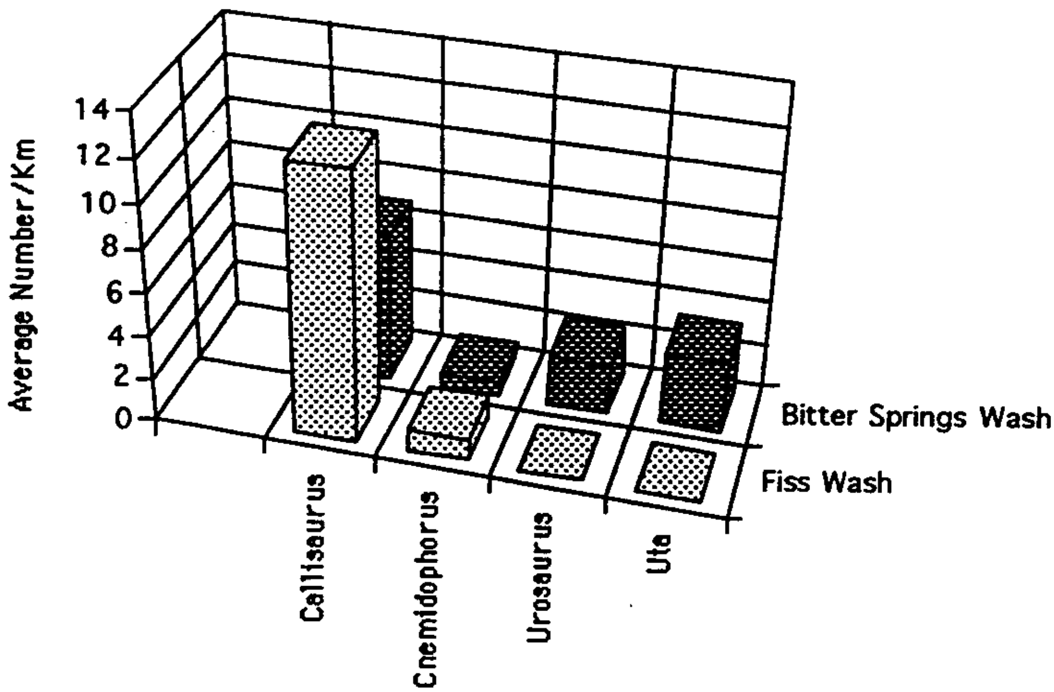
FIGURE 1. CREOSOTE HABITATS, 1994



	Uma	Cnemidophorus	Phrynosoma	Urosaurus	Uta
Red Pass Dunes	5.860	0.570	0.000	0.140	0.000
Bitter Springs Dunes	6.140	1.430	0.140	3.570	0.570

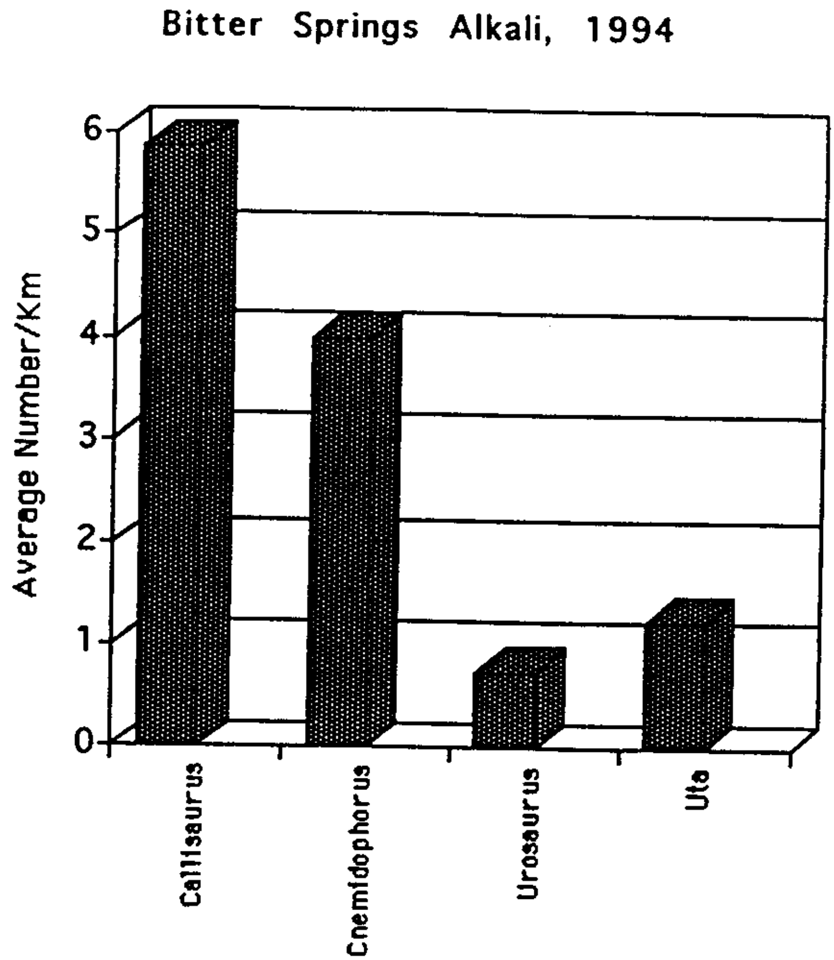
FIGURE 2. DUNES HABITATS, 1994

Wash Habitats, 1994



	FISS Wash	Bitter Springs Wash
Callisaurus	12.400	6.830
Cnemidophorus	1.000	0.670
Urosaurus	0.000	2.330
Uta	0.000	3.330

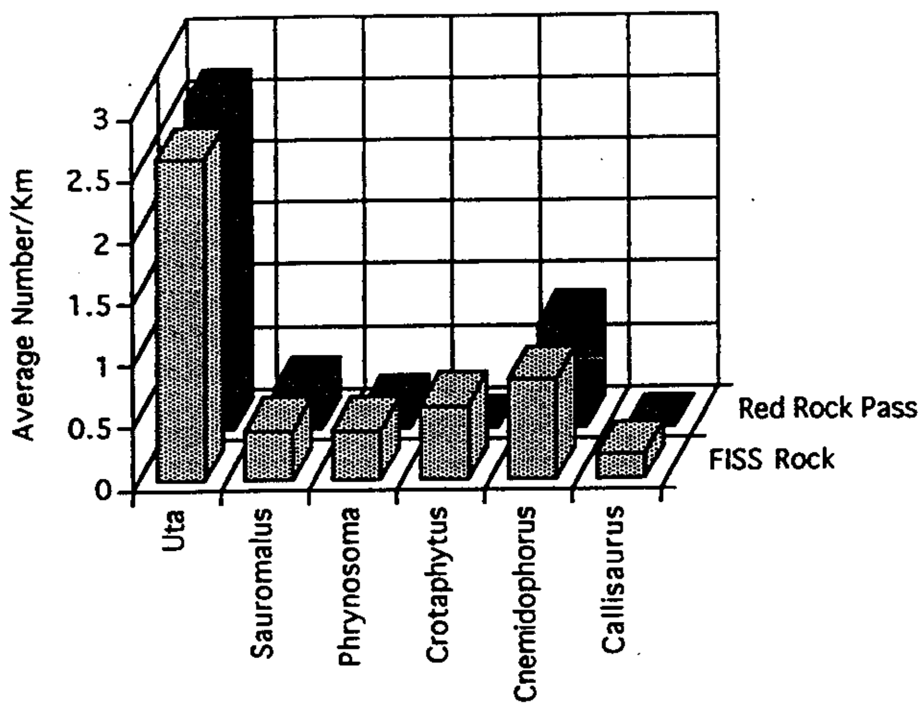
FIGURE 3. WASH HABITATS, 1994



	Callisaurus	Cnemidophorus	Urosaurus	Uta
Bitter Springs Alkali	5.875	4.000	0.750	1.259

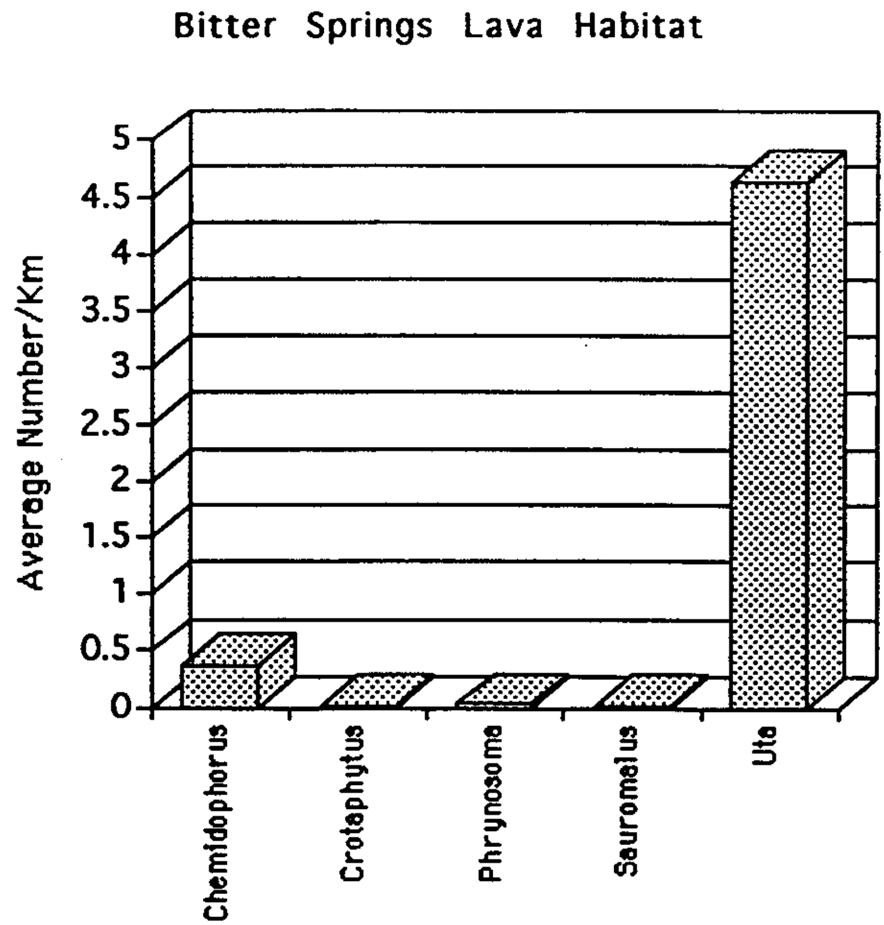
FIGURE 4. BITTER SPRINGS ALKALI HABITAT, 1994

Rock Habitats 1994



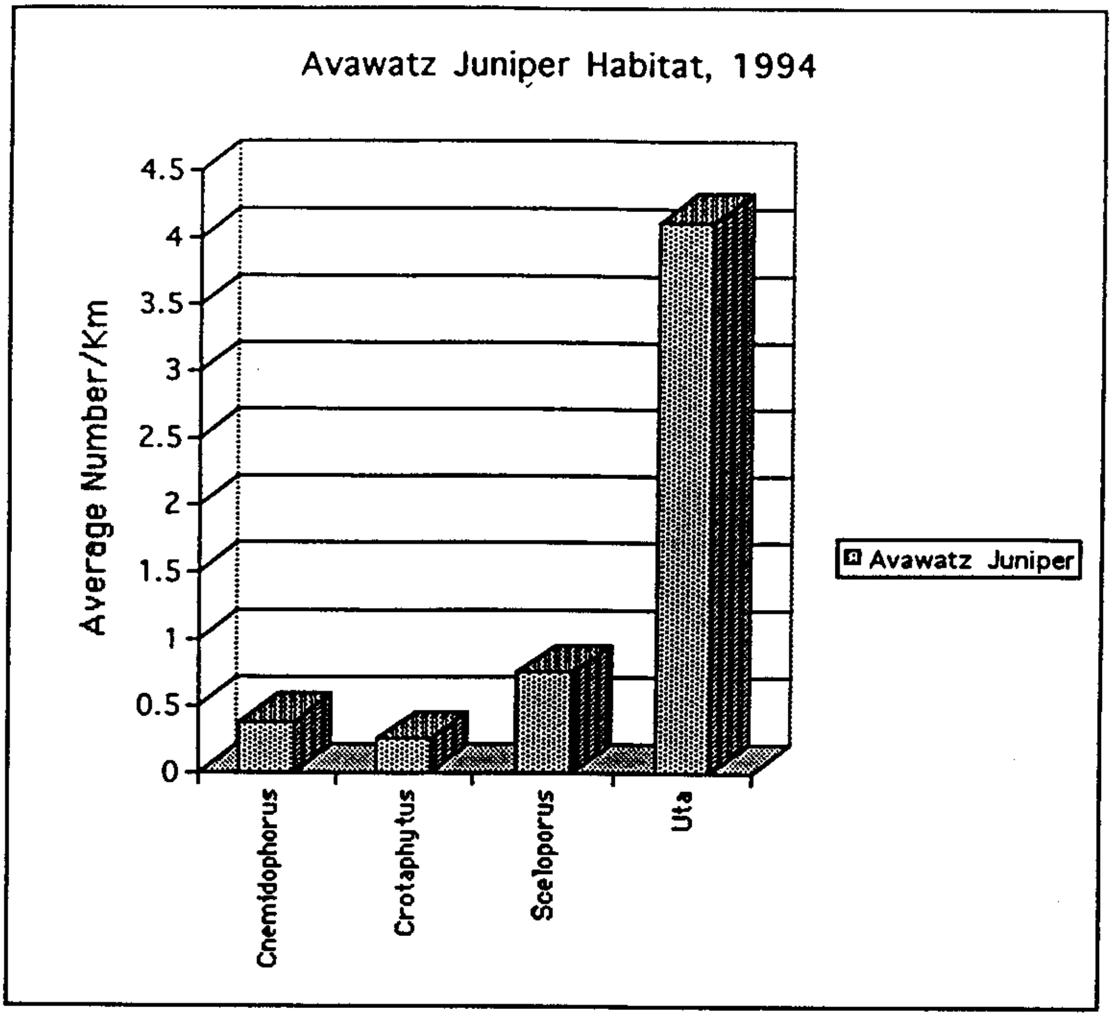
	Red Rock Pass	FISS Rock
Callisaurus	0.000	0.200
Cnemidophorus	0.833	0.800
Crotaphytus	0.000	0.600
Phrynosoma	0.166	0.400
Sauromalus	0.330	0.400
Uta	2.660	2.600

FIGURE 5. ROCK HABITATS, 1994



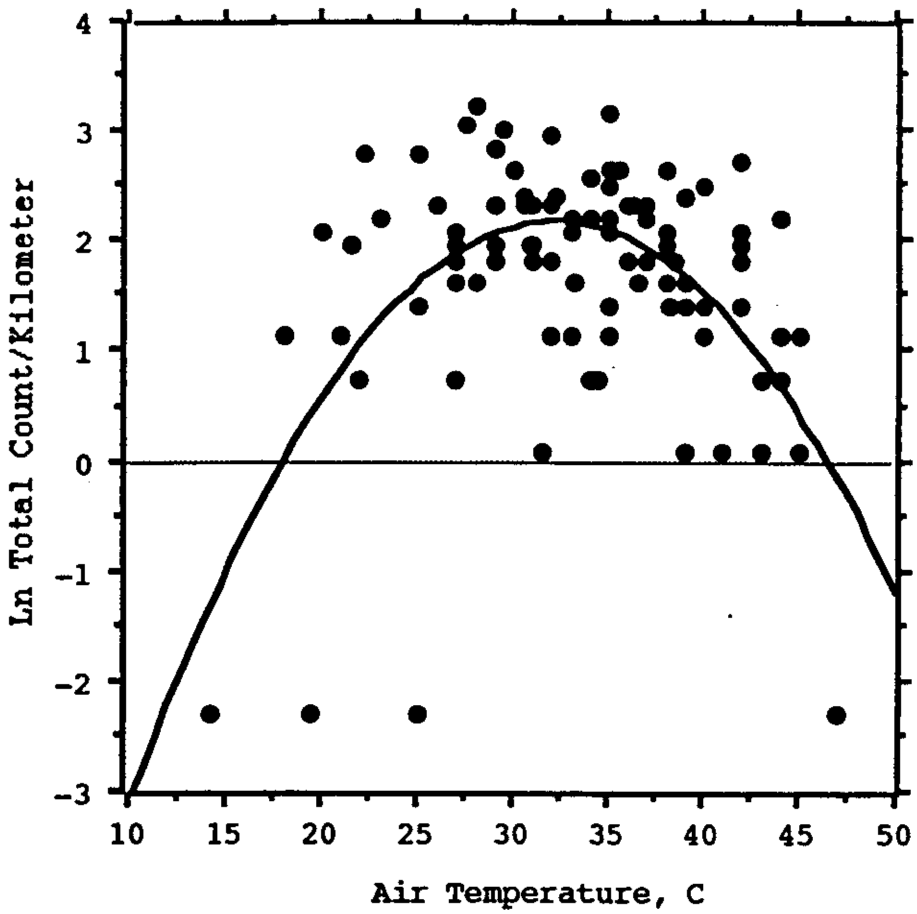
	Cnemidophorus	Crotaphytus	Phrynosoma	Sauromalus	Uta
Bitter Springs Lava	0.0375	0.0125	0.0250	0.0125	4.625

FIGURE 6. BITTER SPRINGS LAVA HABITAT, 1994



	Cnemidophorus	Crotaphytus	Sceloporus	Uta
Avawatz Juniper	0.375	0.250	0.750	4.125

FIGURE 7. AVAWATZ JUNIPER HABITAT, 1994



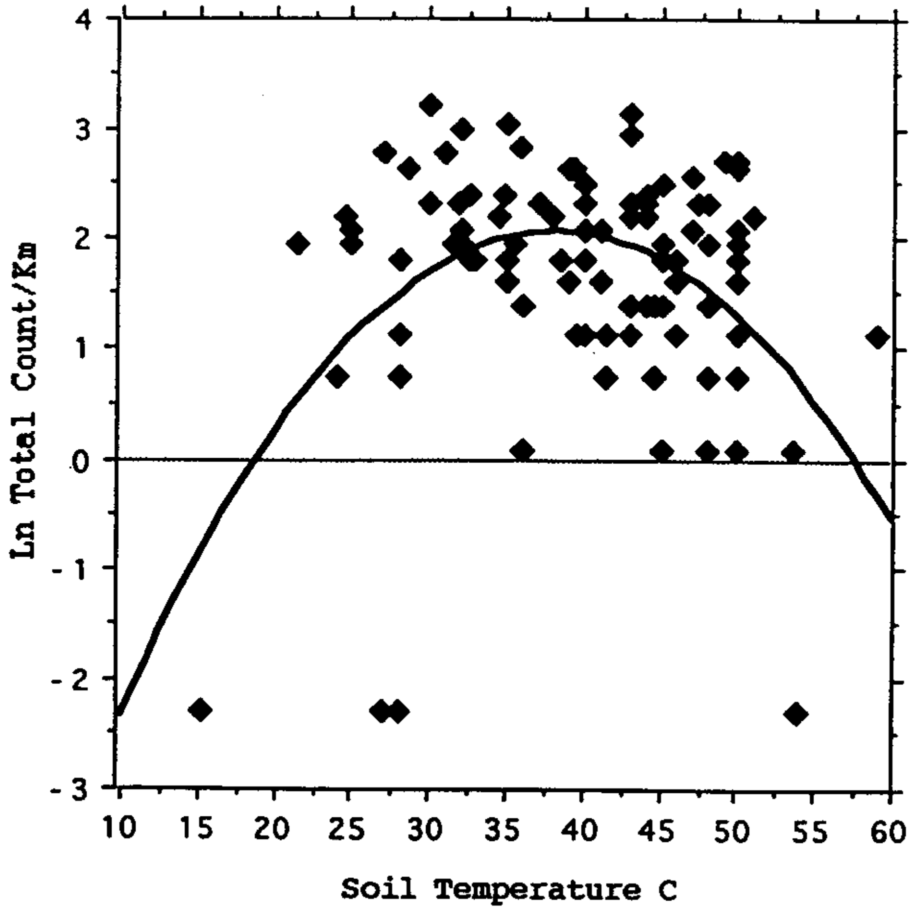
Y = -8.978 + .691 * X - .011 * X^2; R^2 = .329

Polynomial Regression Analysis for the Relationship of Total Average Count/Km* and Air Temperature.

Variable	Coefficient	Std. Err.	t-value	Probability
Intercept	-8.978	1.623	-5.530	<0.0001
Air Temperature, C	0.691	0.102	6.790	<0.0001
Air Temperature, C^2	-0.011	0.002	-6.867	<0.0001

*Total Average Count/Km was transformed into natural logarithms

FIGURE 8. TOTAL AVERAGE COUNT VS AIR TEMPERATURE.



Y = -6.012 + .423 * X - .006 * X^2; R^2 = .185

Polynomial Regression Analysis for the Relationship of Total Average Count/Km* and Soil Temperature

Variable	Coefficient	Std. Err.	t-value	Probability
Intercept	-6.012	1.707	-3.521	0.0007
Soil Temperature, C	0.423	0.091	4.634	<0.0001
Soil Temperature, C^2	-0.006	0.001	-4.674	<0.0001

*Total Average Count/Km is transformed into natural logarithms

FIGURE 9. THE TOTAL AVERAGE COUNT VS SOIL TEMPERATURE

APPENDIX C

Statistical Analysis of Lizard Transects

Statistical Analysis of Lizard Transects

Introduction

Multivariate statistics have been used here to resolve the significance of differences between one kilometer long lizard transect counts which vary by day, time (PST), air and ground temperature ranges, and most importantly, by habitat (vegetation-substrate types). The following information is displayed in sequence:

1. General Summary of 1994 Transect Data

2. Two Factor ANOVA Comparison of all habitats by total lizard abundance

3. Two Factor ANOVA Comparison of Creosote-Alluvium habitat, including Bitter Springs Control (Cr) vs disturbance censuses

4. Two Factor ANOVA Comparison of Dune Habitats

5. Two Factor ANOVA Comparison of Wash Habitats

6. Polynomial Regression for 1994 Total Lizard Counts for All Transects pooled Plotted Against: Soil Temperature, Air Temperature.

7. Histogram Summaries for 1994 transects by habitat:
   a. Creosote
   b. Dune
   c. Rock & Lava habitats
   d. Wash
   e. Alkali
   f. Juniper

Of these presentation, items #1 and #7 are direct summaries of the empirical data. For items # 2-6, commentary is offered here to explain the observed patterns, and tentative conclusions are drawn regarding the refinement of future transect work.

Mean lizard densities per transects demonstrated highly significant differences (P. 0.0001) between habitats. This outcome was expected. Overlap between dates, times, and temperatures were sufficient to minimize factors other than ecotype.

Differences between creosote transects were also highly significant ($P > 0.01$ or >0.001). The percentage of total individuals contributed by different species was a major differentiating factor between sites. As noted in the main text *Callisaurus draconoides*, the zebra tailed lizard, was considerably more abundant in the disturbed Bitter Springs site than in its local control transect. Training may have generated more friable soil surfaces, resembling the loose sand and gravel characteristic of washes so favored by this species. This discovery tends to reject the alternative hypothesis that surface dusts generated by vehicular traffic would be so fine (silt/clay size particles) as to clog lizard nasal passages. Another taxonomic element contributing to site differentiation was the total absence of *Uta stansburiana* from Bitter Springs, both disturbed and control sites. Seasonal, temperature, and temporal bias may account for its absence, since it is widespread in the Bitter springs area including the adjacent alkali (*Atriplex*) flats. It is a small lizard which may avoid competition and predation by early morning and early seasonal (and

Winter) activity at relative low temperatures. Its favorable surface to volume ratio would facilitate thermoregulation in a more limited thermal mosaic of microhabitats. However, since 1994 samples were initiated as early as 25 April and as early as 0800 hrs PST, these explanations appear to be inadequate. Surprisingly, overall diversity was higher in the disturbed Bitter Springs creosote (0.32 vs 0.28) than its control, with the desert horned lizard, *Phrynosoma platyrhinos*, contributing to this diversity. Perhaps moderate disturbance stimulated harvester ant colonization and foraging which, in turn, attracted on of their primary predators, the horned lizard (Recht, personal communication).

Overall differences between the only two dunes ecosystems within or contiguous to Fort Irwin, Bitter Springs and Red Pass, were not significant. However, the absence of *Uta* from Red Pass is surprising, given the position of that dune as 30% slope + incline sand sheet covering the eastern slope of a basaltic ridge. Perhaps sample size was inadequate. Lower relative frequencies of the arboreal long tailed brush lizard, *Urosaurus graciosus*, may accurately reflect the reduced availability of perch sites at Red Pass, where both bush (largely creosote) height and density are reduced relative to Bitter Springs.

As for dunes, the pairwise comparison of Bitter Springs and FISS washes did not reveal significant differences. Both samples were dominated by *Callisaurus*. Prior surveys at these sites, Goldstone (Nagy and Brown, 1995), and others indicate consistency between washes in their high relative frequencies4frequencies of *Callisaurus*.

As for the rock-lava habitat comparisons, again most differences were insignificant, while the three sites revealed some variation in *Sauromalus, Crotaphytus*, and *Uta* densities and relative frequencies. Based on 1993 and other site comparisons, such differences are of doubtful significance and may be more reflective of small samples and site specific daily weather. The large true iguanid chuckwalla, *Sauromalus obesus*, may have been underestimated in cool, early morning and April counts at Bitter Springs Lava. This is a warm desert heliotherm, not active at lower temperatures, effectively the antithesis of diminuative phrynosomatid, *Uta stansburiana*.

The coefficient of determination (R^2) represents the estimated proportion of average total lizard counts explained by the presence of independent variables such as ambient air temperature or ambient soil temperature. Polynomial regressions of this study indicate that nearly 39% of the total lizard count variation may be explained by starting air temperatures. Starting soil temperatures predicted only 18.5% of the variation of total lizard counts. All aspects of the polynomial equations were highly significant (probability < 0.001).

Ambient air temperatures are better predictors of lizard counts because they identify temperature regimes which are universally available to all lizards observed along a transect. Soil temperatures, on the other hand, can vary tremendously within a thermal mosaic that can be modulated by the angular incidence of solar radiation, the distribution of shade, substrate characteristics, angle and aspect, and wind velocity. Recommended procedural changes for future diurnal lizard surveys would include setting minimum starting air temperatures at 27.5 C and maximum starting temperatures at 42.5 C, possibly deleting soil temperatures from the physical measurements, and conducting surveys only during periods of low wind velocities (< 20 mph).

APPENDIX D

Tables

Table 1. 1994 Sampling Schedule and Summary of Site Conditions and Transect Effectiveness

Transect Hub	FISS	RED PASS	BITTER SPRINGS	AVAWATZ
Characteristis				
1. DATES				
April	30		25,28-30	
May	1,15		1	
June	6,9,11,12	4,6,10,14,15		29
July				2,3,7,9,10
2. Time Range (PST)	0600-1200	0643-1253	0815-1525	0850-1254
3. Temperature(C)	31-52	22-56	19->50	38-64
4. Weather *	S,C,W30	S,C,W	S,C,W,R	S,C,W,R
5. Transected habitats	3	3	6	2
6. Total transect runs	19	21	42	10
7. Average run time (minutes)	25	40	30	40
8. Total number Reptiles	177	120	376	34
9. Total species Reptiles	7	8	8	3
10. # Reptile/ transect run	9.3	5.7	8.9	3.4
11. 1993 average # reptiles/transect run = 22				
12. 1994 average # reptiles/transect run = 8				

Note: * S = sun, C = clouds, W = wind, R = rain

Table 2. Relative Abundance of Diurnal Lizards within Major Habitats of the National Training Center, Fort Irwin

	Callisaurus	*Cnemidophorus*	*Crotaphytus*	*Gambelia*	*Urosaurus*	*Sauromaius*	*Dipsosaurus*	*Uma*	*Uta*	*Phyrnospma*	*Other*
FISS Rock	1	4	4	0	0	3	0	0	23	2	1
FISS Wash	79	5	0	0	0	0	0	0	0	0	0
FISS Creosote	21	31	0	0	0	0	0	0	3	0	0
Red Pass Dune	0	4	0	0	1	0	0	41	0	0	0
Red Pass Creosote	6	36	0	0	1	0	2	0	5	0	0
Red Pass Rock	0	5	0	0	0	2	0	0	16	1	0
BSGS Wash	51	5	0	0	19	0	2	1	23	0	0
BSGS Dunes	7	11	0	0	24	0	0	37	4	1	0
BS Dist Creosote	5	6	0	0	0	0	1	2	0	3	0
BSGS Cresosote	47	5	0	0	0	0	5	0	0	0	1
BS Alkali	47	32	0	0	7	0	0	0	10	0	0
BS Lava	0	0	0	0	0	0	0	0	20	0	0
Avawatz Juniper	0	1	0	0	0	0	0	0	14	0	2
Avawatz Creosote	0	5	0	0	0	0	0	0	11	0	1
Total	264	150	4	0	52	5	10	81	129	7	5

Table 3. **Comparisons of Undisturbed vs. Disturbed Creosote-Alluvium Diurnal Lizard Transects at Bitter Springs HUB**

	Undist. 1993 (all sites*)	Undist. 1994	Disturbed 1994
Callisaurus	65% (46%)	81%	29.4%
Cnemidophorus	16 (42)	8.6	35.3
Dispsosaurus	11.6 (3.5)	8.6	5.9
Gambelia	0 (1.6)	0	0
Uma	0 (0)	0	11.8
Uta	2.3 (3.1)	0	0
Urosaurus	2.3 (0.4)	0	0
Phrynosoma	2.3 (1.6)	0	17.6
Totals, N	43 (257)	58	17
# of Species	6 (7)	3	5
X # /transect sweep	11 (10.7)	7.25	2.2

Note: * all sites = the averaged values for all 1993 Eastern NTC creosote alluvium sites combined.

Table 4. Total Pit-fall Trap Results for Bitter Springs Hub for 1993 and 1994

	1993	1994
1. *Uta stansburiana*	29.4 %	07.7 %
2. *Cnemidophorus tigris*	26.1 %	15.4 %
3. *Callisaurus draconoides*	21.6 %	30.8 %
4. *Urosaurus graciosus*	07.2 %	00.0 %
5. *Dipsosaurus dorsalis*	05.0 %	00.0 %
6. **Chionactis occipitalis*	02.7 %	07.7 %
7. *Phrynosoma platyrhinos*	02.2 %	00.0 %
8. *Uma scoparia*	01.6 %	00.0 %
9. *Coleonyx variegatus*	01.1 %	23.0 %
10. *Gambelia wislizenii*	00.5 %	00.0 %
11. * *eptotyphlops humilis*	00.5 %	07.7 %
12. **Phyllorynchus decuratus*	00.0 %	07.7 %
N =	200	13

Note: * = snakes; all others are lizards.

Table 5. Summary of GIS Perceptible Habitats and Associate Diurnal Lizard Assemblages

HABITAT TYPE	% AREA of NTC*	RANKED LIZARD ASSEMBLAGES
Creosote-alluvium	70+	*Callisaurus > Cnemidophorus > Dipsosaurus (SE only) > Sceloporus (NW only)> Uta, Gambelia > Phrynosoma*
Creo-yucca-alluv	10-15	*Uta> Cnemidophorus > Sceloporus m> Callisaurus > Phrynosoma*
Creosote-dune	1	*Uma > Cnemidophorus > Callisaurus > Urosaurus > Gambelia/Dipso > Phrynosoma*
Creo-rocky outcrop	5	*Uta > Cnemidophorus > Sauromalus > Crotaphytus > Phrynosoma*
Blackbush	3	*Uta > Cnemidophorus > Phrynosoma > Callisaurus > Sceloporus*
Juniper-yucca	2	*Sceloporus occidentalis > Cnemidophorus > Uta > Xantusia*

Note: * Surface area estimates are order of magnitude only and do not sum 100 percent. Precise values await the GIS generation of a vegetation map (Lee, Ferrus-Garcia, & Shepard).